Journal of the Royal Society of Western Australia, 76: 53-61, 1993

Holocene vegetation and climate record from Barker Swamp, Rottnest Island, Western Australia

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Manuscript received February 1993; accepted June 1993

Abstract

Palynological and lithological study of a core taken from Barker Swamp, Rottnest Island shows that between 7500 and 6600 years B.P. peat was deposited in an open freshwater lake surrounded by sedges and *Callitris* low forest, with a restricted jarrah/tuart woodland present nearby. Above the peat banded calcilutite sediments contain a succession of charcoal-rich horizons. These are the result of fires that largely destroyed the *Callitris* low forest and caused other elements of the vegetation to decline. The subsequent period of cream-coloured calcilutite deposition started approximately 5300 years B.P. and contains evidence for increased aridity and sparser vegetation. At this level, *Pimelea* and Asteraceae are dominant in the pollen profile and eucalypts decline to abundances consistent with pollen blown from the mainland. *Casuarina* persists as a significant minor element in the pollen profile to the top of the calcilutite interval. A large increase in charcoal and organic material marks the start of European settlement. Later stages of settlement are indicated by increased pollen from eucalypt, *Callitris* and *Melaleuca lanceolata*, a consequence of reforestation on Rottnest Island after 1932.

Introduction

Rottnest Island lies 18 km west of the mainland of Western Australia, offshore from the Perth metropolitan area. It is a hilly, scrub-covered island of approximately 1900 ha, with a series of salt lakes occupying a large portion of the central-eastern part.

The island lies at the northern end of a chain of reefs and islands, formed by Pleistocene Tamala Limestone, that runs south to the mainland through Garden Island. The island chain originally formed a land connection to the mainland; a connection severed about 6500 years ago during the Flandrian transgression (Playford 1988). Recent accounts of the geology of Rottnest Island are provided by Playford & Leech (1977) and Playford (1988).

Eight freshwater, or previously freshwater, swamps exist on the island at the present day (Fig 1): five of these, Barker, Salmon, Lighthouse, Bulldozer, and Parakeet Swamps, are interdunal and two, Bickley and Rifle Range Swamps, both at the eastern end of the island, have been described as shell-flat swamps (Hassell & Kneebone 1960). Most of the swamps were mined for road-building material during the early 1970s and are now hypersaline lakes, but Barker and Rifle Range Swamps were not, probably because of their distance from existing sealed roads. Another unnamed swamp lies to the west of Bickley Swamp (Fig 1). This swamp is thought to be undisturbed and is probably a shell-flat swamp.

The objective of the present study was to examine the pollen record from Barker Swamp for comparison with an earlier pollen study of Lighthouse Swamp reported by Hassell & Kneebone (1960) and Churchill (1960). The study was also intended to demonstrate the potential of Quaternary pollen as a record of recent climatic changes in the Perth region.

Barker Swamp (lat 32° 0' 8"S, long 115° 30' 11"E) occupies approximately one hectare and lies in a hollow near the centre of Rottnest Island, at an elevation of less than 1 m above sea-level. The swamp is bounded immediately to the north by a 25 m high ridge of Pleistocene Tamala Limestone, and to the east, south and west by lower undulating areas of sand covered limestone. It contains the largest undisturbed area of swampland and the greatest known thickness of Holocene sediments of any swamp on the island.

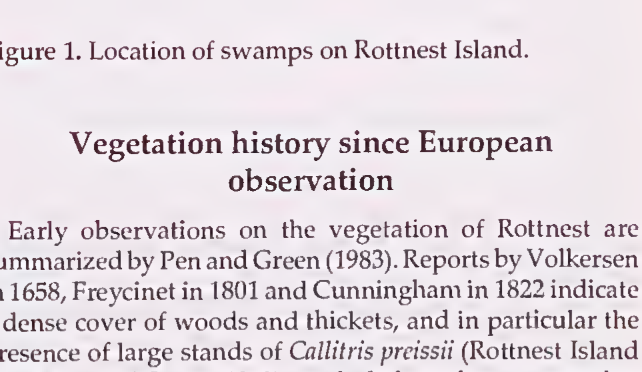


Figure 1. Location of swamps on Rottnest Island.

Vegetation history since European observation

Early observations on the vegetation of Rottnest are summarized by Pen and Green (1983). Reports by Volkersen in 1658, Freycinet in 1801 and Cunningham in 1822 indicate a dense cover of woods and thickets, and in particular the presence of large stands of *Callitris preissii* (Rottnest Island pine). Pen and Green (1983) conclude from these reports that *Callitris* was abundant in the eastern part of the island, but the western part may have consisted of sparsely vegetated sand dunes (Wilson 1829, quoted in Marchant & Abbott 1981).

Forest clearing followed European settlement of the island in 1831. *Callitris* was felled for timber and frequent fires extensively modified the vegetation. *Callitris preissii* and *Melaleuca lanceolata* are not fire tolerant and were extensively reduced. *Acacia rostellifera*, which regenerates after fire by producing suckers, replaced *Callitris* and *Melaleuca* to form dense thickets (Pen & Green 1983). Storr (1963) attributed the decline of *Acacia* scrub since 1930 to a combination of repeated fires and increased grazing by quokkas (*Setonix brachyurus*) since their protection from hunting in the late 1920s. A large fire in 1955 affected the central western part of the island, presumably including the Barker Swamp area. This hastened the spread of *Acanthocarpus-Stipa*, low, dense heath which now covers the hills to the north, west, and east of Barker Swamp. Since 1932 eucalypts, *Melaleuca* and *Callitris* have been established in a number of plantations, and exotic species, including Norfolk Island pines, have been planted sporadically in the Thompson Bay area and elsewhere. A plantation of *Acacia rostellifera* and *Melaleuca lanceolata* occupies low ground within 50 m of the southern margin of Barker Swamp.

Previous studies

Studies of Quaternary pollen on Rottnest Island form part of an unpublished thesis by Hassell & Kneebone (1960) and a brief paper by Churchill (1960).

Hassell put down auger holes in two shell-flat swamps (Bickley and Rifle Range) and four interdunal swamps (Barker, Lighthouse, Salmon and Parakeet) (Fig 1). He considered that the stratigraphy in all the interdunal swamps was essentially similar, despite the differences in thicknesses of individual lithologic units between swamps. Hassell's stratigraphy for the interdunal swamps can be summarized as follows:

1. Upper Peat - approximately 10 cm.
2. Buff Calcilutite.
3. White Calcilutite.
4. Algal Banded Calcilutite - essentially mottled grey and pink calcilutite.
5. Lower Peat.

In Lighthouse Swamp he demonstrated that all lithologic units extend across the swamp and thin significantly towards the margins. Hassell & Kneebone (1960) presented a table showing fossil pollen as a percentage of total pollen for five samples, one sample from each of the stratigraphic units listed above, from an auger hole in Lighthouse Swamp. The Lower Peat, Algal Banded Calcilutite and White Calcilutite pollen spectra are dominated by Chenopodiaceae and Cyperaceae. The Buff Calcilutite contains common Chenopodiaceae, Poaceae, Cyperaceae and Euphorbiaceae, and the Upper Peat contains 98% Chenopodiaceae. Eucalypt pollen is present at all levels, but is most abundant in the Lower Peat (5%) and the Buff and White Calcilutite (4% and 6% respectively). Only 100 pollen in total were counted for each sample, and therefore the eucalypt pollen count is too small to be statistically significant.

Churchill (1960) presented fossil pollen data, evidently based largely on the work of Hassell. Churchill also compared the fossil pollen record from Lighthouse Swamp and Serpentine Lake with the modern (*c*.1960) atmospheric pollen count at the Rottnest Island Biological Research Station, and at an unspecified location on the adjacent mainland. Among other conclusions, he suggested that eucalypt pollen gradually decrease through the sedimentary record, and the number of eucalypts present on the island during the early period of peat deposition was similar to the number on Rottnest in about 1960. He also observed that *Callitris* pollen is abundant in the fossil record, although it was not recorded by Hassell.

Churchill (1960) reported a date on a fossil blackboy (*Xanthorrhoea*) stump from a depth of 19ft (5.75m) at an unknown locality on the island. It was dated at 7090 ± 115 yr B.P. He also recorded the find of a piece of *Callitris* wood in the "Rottnest Shell Beds", now called the Herschell Limestone.

The statement by Storr *et al.* (1959) that "a tuart woodland similar to that of the present mainland once existed" on Rottnest is presumably based on the evidence subsequently presented by Hassell & Kneebone, (1960) and Churchill (1960) and discussed above. This conclusion has been re-stated several times, most recently by Pen and Green (1983) and Playford (1988). It relies on the undoubted former presence of *Xanthorrhoea* and the perceived greater abundance in the fossil record of species typical of tuart woodland, including several species of *Eucalyptus*.

Methods

Samples were collected for the present study using a post-hole digger with a 13 cm cut, a hand auger and a hand operated, D-section corer.

Two test holes were used at Barker Swamp to ascertain the sedimentary thickness and the best methods of sample collection in the different lithologies. In the third hole, Barker Swamp 3, cores were cut down to the top of the Lower Peat and the hole continued by auger through the peat to the underlying sand.

The upper layers of calcilutite were too stiff to allow full 50 cm cores to be cut using the D-section corer. In this lithology the hole was widened with the post-hole digger after each short run (usually less than 30 cm) for easier access. Cores were taken alternately from opposite sides at the bottom of the widened hole. In the Banded Calcilutite and upper part of the Lower Peat the sediments were soft enough to permit full 50 cm cores to be taken on each run and hole widening was unnecessary. The depth of each core-run was carefully measured from the swamp surface and each core overlaps the previous core by at least 12 cm. Fourteen cores were cut in Barker Swamp 3 between 16 and 329 cm, and the surface material to a depth of about 20 cm was sampled with a spade. The corer had only sufficient extension rods to reach 329 cm. Below this depth samples were collected with the hand auger to a depth of 401 cm. A set of near surface samples were collected from a small trench.

Some core samples were obtained for comparative purposes from Salmon Swamp. In this swamp, banded calcilutite and sandy peat extend for 158 cm below the excavated surface before grey sand is reached.

Samples were prepared using standard acetolysis methods as outlined by Faegri & Iverson (1975) and Moore & Webb (1978), with brief oxidation used on some samples. Initially glycerine jelly was used as a mounting medium, but later preparations were mounted in silicone oil. *Lycopodium* tablets, either whole or in solution, were added to allow estimation of the pollen concentration.

In the peat sections, 1 cm^3 of sample was sufficient to produce enough organic material for analysis. In the Banded Calcilutite 2 or 3 cm^3 of sample was used, and in the calcilutite 4 cm^3 of sample was required.

Dinoflagellate cysts are abundant in many samples in the Banded Calcilutite and Calcilutite. They were counted up to the first 25 or 50 *Lycopodium* spores. Pollen groups were usually counted up to 100 *Lycopodium* spores. In most samples a minimum of 200 pollen grains were counted, in a few sparse samples counts were between 100 and 200, and in two samples (16.5 and 18.5 cm) because of the infrequency of pollen fewer than 100 were counted.

Many of the rarer taxa could not be identified unequivocally to family level. Fortunately, the most common pollen taxa are well known at family or generic level because of their frequency in Quaternary deposits.

Radiocarbon dates from Barker Swamp

A pooled group of auger samples from slightly above the base of the peat in Barker Swamp 3 gave a conventional radiocarbon date of 7220 ± 210 yrs B.P., and a sample from core 13 (302-309 cm), near the top of the peat, gave a date of 6850 ± 360 yrs B.P. Accelerator mass spectrometry dating of a small sample from the 197 cm charcoal band gave a date of 5645 ± 72 yrs B.P. (NZA 2774) (Fig 4).

Stratigraphy of Barker Swamp

The Barker Swamp sequence is divided here into four broad lithologic units. In descending order these are:

Surface Peat	0 - 13 cm
Calcilutite	13 - 169 cm
Banded Calcilutite	169 - 296 cm
Lower Peat	296 - 394 cm

Significant variation occurs within each unit (Fig 2). The Lower Peat is underlain below 394 cm by medium grained, grey, quartzose sand, which probably overlies Tamala Limestone at depth.

The Lower Peat, from 296 to 394 cm, consists predominantly of black to dark brown peat with clearly distinguishable fragments of leaves that appear to be mainly Cyperaceae. Abundant molluscs, ostracods, and fine shell material impart a silty appearance to the lower part. Ostracods and fine shell material are less frequent in the upper part where dense black peat predominates. The fine organic maceral content of the Lower Peat includes occasional charcoal, frequent algal filaments and fungal spores, and abundant fibrous leaf and stem remains. *Botryococcus* and *Pediastrum* are present at some levels.

The Banded Calcilutite interval extends between 169 and 296 cm. It consists of a series of thin, dark-grey, charcoal-rich bands, usually overlain by chocolate-brown, fine-grained calcilutite (essentially a lime mud with varying minor amounts of organic material), interbedded with thicker

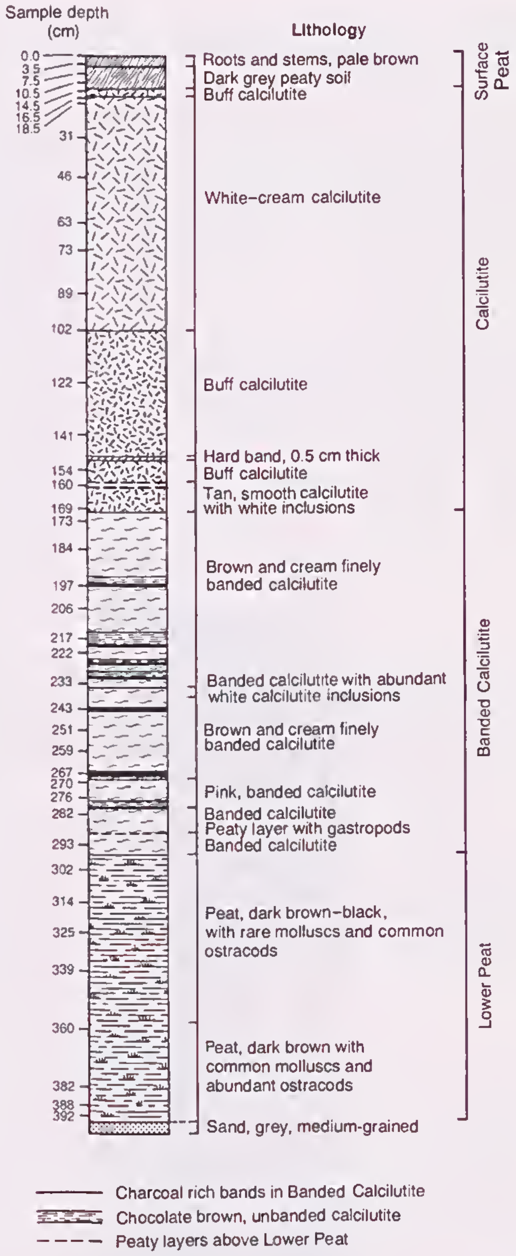


Figure 2. Lithologic column for Barker Swamp 3.

intervals of finely banded sediments. A thin layer of peaty material with abundant shells of the snail *Physastra* occurs at 289 cm, a short distance above the Lower Peat. The base of each major charcoal band is sharply delineated and the upper boundary is diffuse, with charcoal fragments reducing gradually up section. Major charcoal rich bands occur at 279, 267, 243, and 197 cm. Less prominent charcoal bands are clustered between 215 and 235 cm (Fig 2). In some intervals of the Banded Calcilutite, where the banding is well defined, individual fine bands can be distinguished and counted. Each band is 0.75-1.5 mm thick and consists of cream-coloured calcilutite overlain by a brown, organic-rich layer. The interval between 269 and 277 cm is a distinctive pink colour, in contrast to the brown colour of the Banded Calcilutite in other intervals.

Charcoal is more common at all levels in the Banded Calcilutite than in the Lower Peat. In the charcoal-rich bands it is often the dominant maceral. In banded intervals, *Botryococcus*, amorphous algal material, and small, subspherical algal cysts comprise the bulk of the organic material. Dinoflagellate cysts are abundant in several samples in the upper part above 259 cm.

The sequence of light and dark layers, produced by variation in charcoal content, in the lowest part of the Banded Calcilutite in Barker Swamp is replicated in the corresponding interval in Salmon Swamp. Figure 3 shows the lower Banded Calcilutite interval in Barker Swamp between 248 and 296 cm, with the top of the Lower Peat, and the 279 and 267 cm charcoal bands indicated. The equivalent interval in Salmon Swamp is shown alongside. The major fires that affected Barker Swamp also appear in the sedimentary record of Salmon Swamp, 1 km to the south, evidence that these were substantial fires. The similarity in the banding pattern between the two cores suggests that it may be possible to finely correlate the entire Banded Calcilutite interval between these two sites.

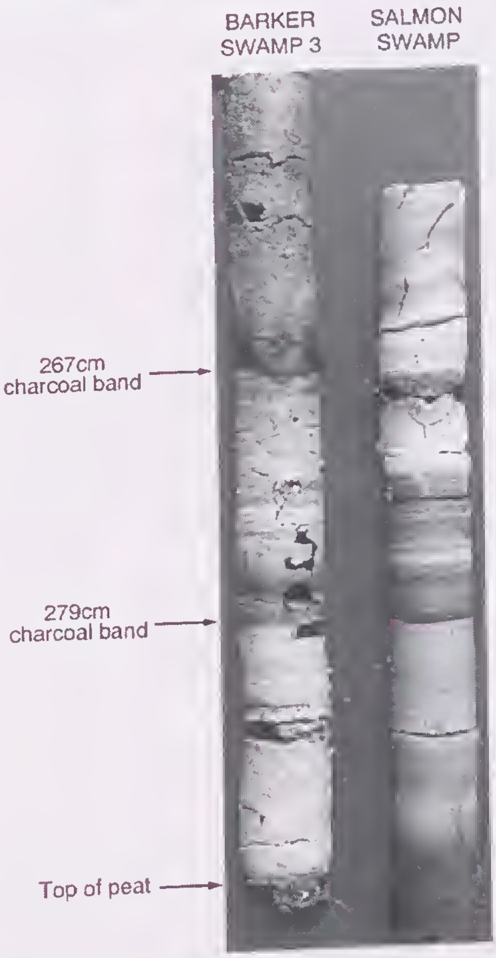


Figure 3. Comparison of the lowest Banded Calcilutite intervals in cores from Barker Swamp and Salmon Swamp.

The boundary between the Banded Calcilutite and the overlying Calcilutite is transitional. Visible organic fragments decrease gradually as banded calcilutite gives way to pale, chocolate-coloured calcilutite. The interval included in the Calcilutite is from 13 to 169 cm. Buff-coloured calcilutite occurs predominantly in the lower part, in contrast to the swamp stratigraphy outlined by Hassell & Kneebone (1960). Lithologically the Calcilutite consists of white to cream, or buff-coloured, chemically precipitated, lime mud, with abundant ostracod carapaces. At the top, a narrow band of buff-coloured calcilutite immediately underlies the dark Surface Peat. Cream-coloured calcilutite extends down to 102 cm, and below 102 cm the calcilutite becomes buff-coloured and then chocolate brown. Two thin, slightly peaty, horizons occur at a depth of about 160 cm.

A hard band of semi-cemented calcilutite, 0.5 cm thick, occurs at 143 cm, and less cemented hard bands occur just above this level. A better developed hard band is present in Salmon Swamp at a depth of 78 to 79 cm below the excavated surface, in a similar stratigraphic postion to the hard band in Barker Swamp. These hard bands are assumed to indicate a period of desiccation that affected both swamps.

Charcoal is infrequent in the Calcilutite. In the lower part dinoflagellate cysts and amorphous algal material are still common and in the highest part, between 16.5 and 63 cm, small subspherical algal cysts dominate the assemblages. This changes abruptly in the 14.5 cm sample, in buff calcilutite, where amorphous algal material, leaf remains, and charcoal are more frequent.

The carbonaceous interval between the surface and 13 cm is referred to as the Surface Peat, although it is not a true peat. It can be subdivided into a lower layer of charcoal rich, dark grey, sandy, calcareous sediment between 5 and 13 cm and an upper, pale brown, spongy layer, with less frequent charcoal and composed largely of *Sarcocornia* roots and stems.

Microfauna

Ostracods and molluscs were examined from 8 samples in Barker Swamp 3. Species presence at different sample depths is shown in Table 1.

De Deckker (pers comm. 1991) considers that *Mytilocypris tasmanica chapmanii, M. ambiguosa, Diacypris spinosa,* and *Cyprideis* aff. *australiensis* tolerate slightly saline water. These species are present in the Banded Calcilutite and Calcilutite, but only C. aff. *australiensis* is also present in the Lower Peat. The other species recovered from the Lower Peat favour fresh-water conditions; *C. tenuis* can tolerate swampy conditions and *K. cristata* is often associated with oligotrophic conditions. From the abundance of the latter species in the Lower Peat it is concluded this unit was deposited in a small, open, freshwater lake.

	Surface	92-98 cm	123-131 cm	165 cm	230-262 cm	314-317 cm	358-363 cm	386-394 cm
Ostracoda								
Alboa worooa	A							
Mytilocypris tasmanica chapmanii	C	C	C	C	R			
M. ambiguosa	C							
Diacypris spinosa		R		R	R			
Cyprideis aff. *australiensis*		R		R	A	R	R	R
Kennethia cristata						A	C	C
Candonopsis tenuis						R		R
Mollusca								
Coxiella striatula	A							
Physastra sp.						C	C	R
Ferrissia sp.						C	C	R
cf. *Paraloma* sp.								R
Austrosuccinea sp.								R
Gastropod sp. A (Carithiacea)								R

Table 1.

Stratigraphic distribution of ostracods and molluscs in Barker Swamp 3; A, abundant; C, common; R, rare.

Edward (1983) related several of the above ostracods to water salinity in a study of fauna from inland waters on Rottnest. *K. cristata, A. worooa* and *M. ambiguosa* are present in the salinity range 1 - 14.8 ppm, and *D. spinosa* has a salinity range of 2.4 - 44.0 ppm.

Of the molluscan fauna, *Physastra* is a pond snail known from fresh and brackish waters, and *Ferrissia* is a freshwater limpet. *Austrosuccinea* and cf. *Paraloma* sp. are terrestrial snails washed into the lake. *Coxiella striatula* is common in saline and brackish inland waters.

Pollen diagram

The pollen diagram for Barker Swamp (Fig 4) indicates significant changes in the vegetation at this locality over the past 7500 years. The greatest changes approximate the major lithologic boundaries outlined above. Pollen taxa are shown as a percentage of the total pollen spectra. A few pollen types that are extremely rare and unidentified taxa, which comprise less than 2% of total pollen in most samples, are not shown.

In this study, *Eucalyptus* type A includes pollen that is probably *E. gomphocephala* (tuart), *E. marginata* (jarrah) and *E. todtiana*, taxa whose pollen seems to be rather similar in appearance. All other eucalypt pollen is categorized together. Because of special interest in the previous presence of eucalypts on the island, the *Eucalyptus* pollen concentration is also given as this better illustrates the actual abundance of this pollen type in the sediments.

The pollen characteristics of the four lithologic units are summarized below:

Lower Peat: Pollen concentration low at the base, increasing to the top; *Callitris* and Cyperaceae high to moderate; Asteraceae, *Casuarina*, Poaceae, Restionaceae, Rutaceae and *Eucalyptus* low. *Pimelea* absent. *Xanthorrhoea* present at 392 cm and a single *Banksia* at 339 cm

Banded Calcilutite: Pollen concentration initially high, decreasing to the top; *Callitris* high to low; Asteraceae, Chenopodiaceae, *Eucalyptus* and *Pimelea* (in upper part) moderate to low; Cyperaceae, *Casuarina*, Poaceae, Restionaceae, Rutaceae, Portulacaceae and *Melaleuca* low.

Calcilutite: Pollen concentration extremely low; *Pimelea* and Asteraceae relatively high; *Casuarina, Eucalyptus*, Restionaceae and Chenopodiaceae low to moderate; Cyperaceae, Rutaceae and *Melaleuca* low; *Callitris* absent.

Surface Peat: Pollen concentration high; Chenopodiaceae extremely high; *Eucalyptus* and *Melaleuca lanceolata* low; Cyperaceae, Asteraceae, *Casuarina*, Poaceae, Restionaceae and Rutaceae present, but very rare; *Pimelea* absent. *Acacia* present in surface sample.

History of Barker Swamp

Sedimentation at the Barker Swamp site commenced with the establishment of a fresh, openwater lake approximately 7500 yrs B.P., near the end of the sea-level rise that followed the last glaciation and which eventually separated Rottnest Island from the mainland (Playford 1988). The lake contained a diverse freshwater fauna and occasional dinoflagellates. It was surrounded by sedges (Cyperaceae), probably *Gahnia trifida* and *Isolepis nodosa* the most common species extant on Rottnest. *Callitris preissii* dominated the vegetation beyond the fringes of the lake, and probably formed a low forest similar to the *C. preissii* low forest still present on Garden Island. *Casuarina* and *Eucalyptus* were less common or more distant elements of the vegetation. *Xanthorrhoea* was present in the vicinity of the swamp for at least the first two or three hundred years, while melaleucas, including *M. lanceolata*, were rare elements of the flora.

Limited evidence from the lower peaty layer in Salmon Swamp, where Chenopodiaceae pollen is abundant, indicates that this swamp was more saline than Barker Swamp during the Lower Peat period. This accords with the pollen record from the Lower Peat in Lighthouse Swamp (Hassell & Kneebone 1960)

On the assumption that peat accumulation in Barker Swamp ended approximately 6600 yrs B.P., the rate of accumulation of the Lower Peat is estimated at about 10 cm per 100 yr.

Open freshwater swamp conditions gave way to rather more brackish conditions and deposition of calcilutite with thin organic-rich bands. A peaty layer with freshwater gastropods at 287 cm represents a brief return to the conditions that prevailed during deposition of the peat. The change in sedimentary regime is coeval with the disappearance of freshwater molluscs, and the ostracod fauna shifted towards species more tolerant of brackish water. At the swamp margin, sedges declined and salt-tolerant chenopods increased. *Callitris* still dominated the surrounding area, and *Eucalyptus, Casuarina, Melaleuca*, Poaceae, Restionaceae and Rutaceae (particularly *Diplolaena*) gradually became more common.

A fire, represented by the charcoal band at 279 cm, appears to have had little effect on the overall abundance of *Callitris*, but a subsequent and probably larger fire, represented by the 267 cm charcoal band, dramatically reduced the number of *Callitris*. A further major fire, indicated by the 243 cm charcoal band, and a series of smaller fires, represented by a series of thinner charcoal bands up to 185 cm, eliminated most of the *Callitris* in the Barker Swamp area. However, a few *Callitris* regenerated and survived, as evidenced by the presence of *Callitris* pollen near the top of the Banded Calcilutite interval at 173 cm.

The concentration of eucalypt pollen decreases significantly above the charcoal bands at 279 and 267 cm, from which it is concluded that the eucalypts, as well as *Callitris preissi*, were seriously affected by these fires.

The charcoal band at 267 cm is followed by an increase in the percentage of Chenopodiaceae and Asteraceae pollen, but it is not certain that this represents an actual increase in frequency of these taxa because the pollen concentration falls sharply at this level. *Pimelea* pollen appear in the record for the first time between the 267 and 279 cm fires, and increase in relative abundance to become the dominant taxon in the pollen record by the top of the Banded Calcilutite. By this time vegetation in the area of Barker Swamp was predominantly low scrub with occasional *Callitris, Eucalyptus* and possibly *Casuarina*. The land connection with the mainland was probably severed during the Banded Calcilutite period. The subsequent removal of population controls on

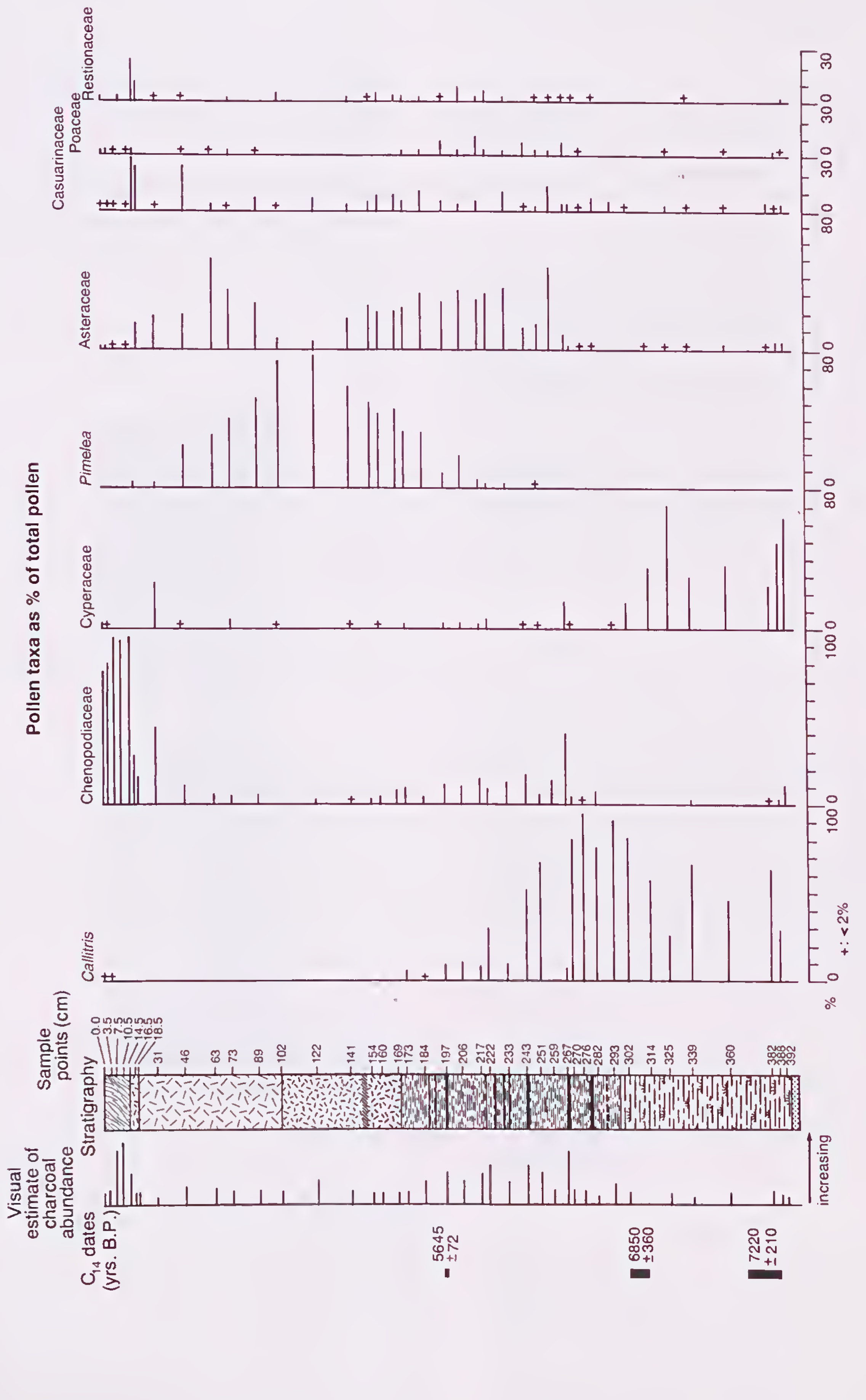
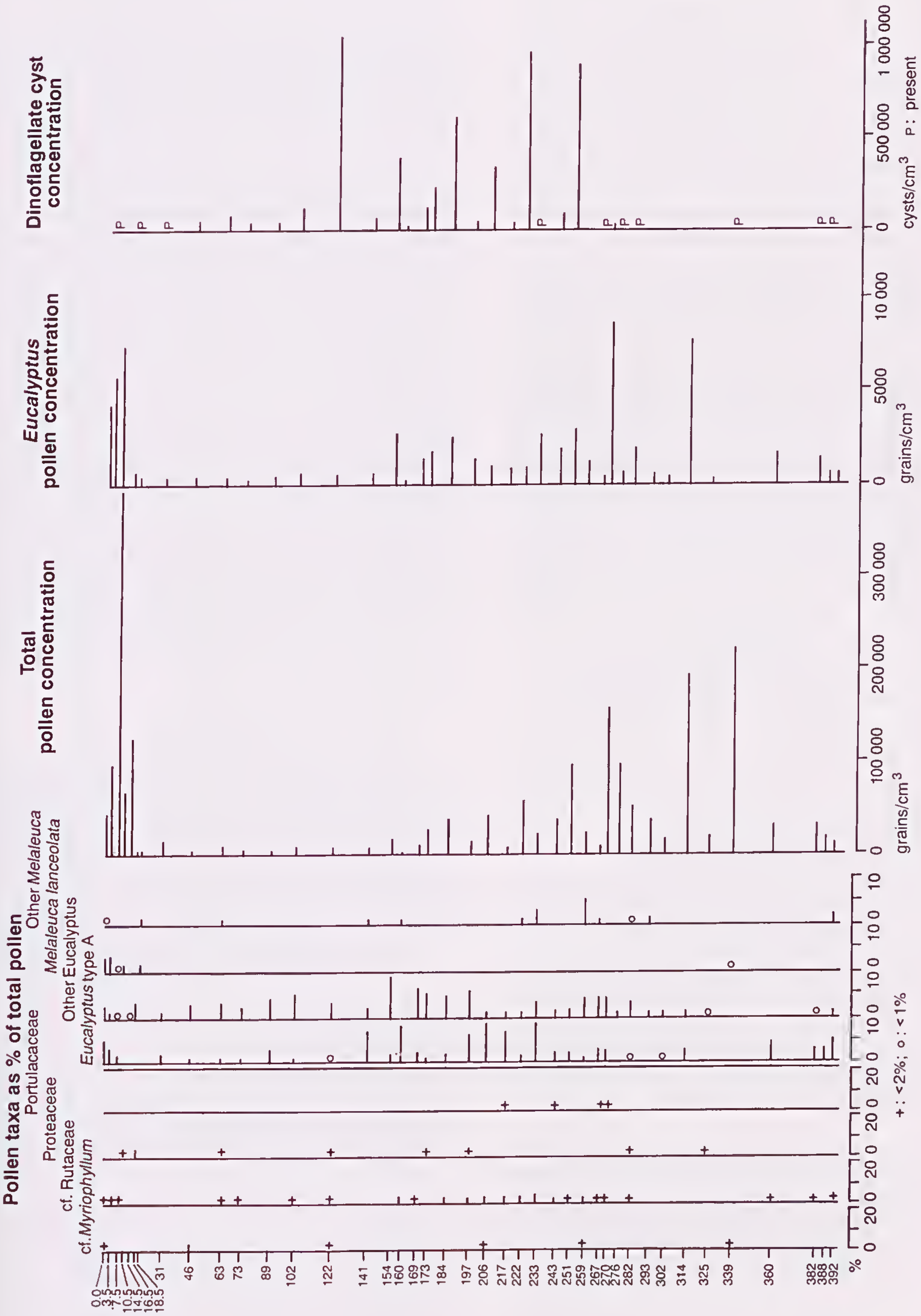


Figure 4. Barker Swamp 3: radiocarbon dates, charcoal abundance, stratigraphy, percentage pollen diagram, and pollen and dinoflagellate cyst concentration diagram. (cont. next page)



Pollen taxa as % of total pollen
cf. Myriophyllum
cf. Rutaceae
Proteaceae
Portulacaceae
Eucalyptus type A
Other Eucalyptus
Melaleuca lanceolata
Other Melaleuca
Total pollen concentration
Eucalyptus pollen concentration
Dinoflagellate cyst concentration
+: <2%; o: <1%
grains/cm3
cysts/cm3
P: present

quokkas, except for food and water availability, may have led to greater grazing pressure, thus further restricting vegetation regrowth after fires.

During most of the Banded Calcilutite period the annual cycle of sedimentation in Barker Swamp consisted of deposition of a layer of algal material, probably in spring, followed by precipitation of calcium carbonate. In the periods following fires this pattern of sedimentation was disrupted. Instead of annual layering the sediments deposited during these periods consist of unlayered charcoal-rich bands, often followed by thicker layers of charcoal-rich, chocolate-brown calcilutite. The fires clearly affected sedimentation in the swamp for a period estimated to be at least 5 to 10 years, and possibly up to 40 years or more in some cases.

The 197 cm charcoal band is dated at 5645 ± 72 years B.P., which gives a sedimentation rate from the top of the Lower Peat to 197 cm of about 10 cm per 100 years. Assuming a uniform sedimentation rate for the whole of the Banded Calcilutite in Barker Swamp, deposition of this unit ceased approximately 5300 years B.P. This is within the period of sea-level high stand when much of the eastern part of Rottnest was inundated by the sea (Fairbridge 1958, Playford 1988).

In the succeeding Calcilutite interval, dinoflagellate cysts and subspherical algal cysts comprise much of the organic content. Plant debris and pollen are much less abundant, which suggests that the local vegetation was considerably sparser than in the preceding period. Darker bands with large quantities of charcoal have not been observed in the Calcilutite and it is concluded that fires became infrequent, or of much lower intensity, after about 5000 yrs B.P. The disappearance of fire-prone vegetation such as *Callitris* and *Eucalyptus* from the central-western part of the island is the most likely reason for this absence of significant fires.

The thin, cemented, hard band at a depth of 143 cm (estimated at about 4500 years B.P.) represents a period of severe desiccation, probably the result of a prolonged period of low precipitation. This is in agreement with Kendrick's (1977) record for reduced winter flows in the Swan River system during a mid Holocene dry period.

The hard band at 143 cm also marks the start of a period of extremely low rate of pollen deposition (Fig 4). Eucalypts were not regenerating in the area of Barker Swamp, and possibly nowhere on the island, at this time. This is also towards the end of the period of sea-level high-stand when the eastern part of Rottnest was inundated, with destruction of the remaining stands of eucalypts. Eucalypt pollen concentrations of fewer than 600 grains cm^3 of sediment between depths 14.5 and 141.0 cm in the Barker Swamp profile are interpreted as representing pollen blown from the mainland.

The absence of significant further changes in the pollen record through the Calcilutite indicates that conditions remained relatively arid through this period. From the pollen record, vegetation on the low ground arround the swamp became dominated by *Pimelea*, with Asteraceae as the only other significant element of the flora.

The dominance of *Pimelea* and Asteraceae waned towards the end of the Calcilutite period. Chenopodiaceae, Cyperaceae, Restionaceae and *Casuarina* pollen all show patchy increases in relative abundance near the top of the Calcilutite. This may indicate a slight increase in precipitation in the period immediately preceding European settlement, but the very low pollen concentration at this level precludes any firm conclusion on the cause of this change.

The record of *Casuarina* and *Pimelea* pollen is particularly interesting because neither are recorded from Rottnest as part of the original vegetation at the time of European settlement. *Pimelea* declined dramatically in the period immediately preceding settlement of the island, and is not observed in the pollen record above 16.5 cm, the highest sample representing pre-settlement conditions. Several factors may have caused its decline; amongst them grazing by quokkas and increased competition from chenopods, Cyperaceae and Restionaceae. Quokkas on Rottnest found *Pimelea* highly palatable when offered shoots brought from the mainland (*pers. obs*). Grazing by domestic animals and more frequent fires after settlement possibly caused the final extinction of *Pimelea* on Rottnest. *Casuarina* is a major element in the pollen record at the top of the Calcilutite in an interval where the pollen concentration is extremely low. Casuarinas are wind pollinated and produce pollen in large quantities. It is possible that all or most of the *Casuarina* pollen in the Barker Swamp core was derived from the mainland. However, the frequency and consistency of *Casuarina* in the pollen record suggests that *Casuarina* was present on Rottnest in the past, and may have survived up to European settlement.

It is evident from the radiocarbon dates, and assuming continuous sedimentation, that the rate of accumulation of the Calcilutite interval was slower than the Lower Peat and Banded Calcilutite. If a date of 5300 years B.P. is accepted for the top of the Banded Calcilutite, and the change to buff-coloured calcilutite at 16 cm is taken as the start of European settlement in 1838, then the Calcilutite accumulated at a rate of approximately 3 cm per 100 yr.

The closely spaced samples at the top of the Barker Swamp section reveal the effects of European settlement. A sample of buff-coloured calcilutite from 14.5 cm contains considerably more charcoal than the immediately underlying sample at 16.5 cm. It also contains abundant chenopod pollen, but very few other pollen types. This sample is interpreted as representing the period of very early settlement when a small amount of burning and grazing had taken place. Charcoal is extremely abundant at 10.5 cm, and the pollen profile is essentially unchanged from the previous sample at 14.5 cm, except for a decline in the already low *Eucalyptus* count below detection levels. This represents a period of more intense fires on Rottnest, and the clearing of eucalypts on the mainland.

Reforestation on Rottnest started as early as 1886 (Sten 1959), but early efforts were largely unsuccessful. Major plantings of *Eucalyptus gomphocephala* started in 1932, and the large plantation at the western end of Serpentine Lake was planted between 1934 and 1944 (Sten 1959). The samples from 7.5, 3.5 cm and the surface show declining amounts of charcoal, still abundant chenopods, much higher concentrations of *Eucalyptus* and significant numbers of *Melaleuca lanceolata*. The two highest samples contain small numbers of *Callitris*, and pine pollen (not shown in Fig 4) comprises 0.5% of the pollen at 3.5 cm and 2% in the surface sample. The sharp increase in eucalypt pollen concentration in the 7.5 cm sample is the result of extensive eucalypt planting on Rottnest after 1932.

Despite the rather different sedimentary regimes, the eucalypt pollen concentration in the Surface Peat (0.0-7.5 cm samples) can be compared with the pollen concentration in the Banded Calcilutite and Lower Peat. On the available pollen evidence, eucalypts were no more common in the central part of the island 5000 to 7500 years ago than they are at the present day, although their distribution was probably different. An assessment of past eucalypt abundance on other parts of the island must await study of the pollen record from other sites.

Although *M. lanceolata* and *Callitris preissii* are known to have been quite common on the eastern part of the island at the time of European settlement (Pen & Green 1983), the pollen record suggests that *M. lanceolata* was a minor component of the vegetation in the vicinity of Barker Swamp until recent times. *C. preissii*, on the other hand, was once the dominant species, but it is not recorded in the pollen record between 7.5 and 169 cm. It is assumed that planting of *C. preissii* and *M. lanceolata* in areas near Barker Swamp has increased the number of pollen from these taxa in the Surface Peat.

The presence of *Acacia* pollen only in the surface sample accords with Churchill's (1960) recorded absence of *Acacia* pollen from the sediments of Lighthouse Swamp. *Acacia* polyads break down readily into undistinguished individual pollen. Isolated *Acacia* pollen were not observed in samples below the surface, despite careful examination of samples in the Surface Peat. It is concluded that *Acacia* was rare or absent in the past in the Barker Swamp area, and the presence of *Acacia* pollen in the surface sediments results from the recent introduction of *Acacia* to the area.

Conclusions

Comparison of cores from Barker and Salmon Swamps shows that the sequence of dark and light bands immediately overlying the Lower Peat is similar at both sites. By using this banding it may be possible to produce fine correlation between banded sediments from some or all of the swamps on Rottnest. If so, the same horizon could be sampled at several sites. Comparisons could then be made of the pollen flora and the microfauna between sites for coeval intervals, thus producing a series of palaeo-vegetation maps for the central-eastern part of the island.

This study did not replicate the results of Hassell & Kneebone 1960) at Lighthouse Swamp, partly because the vegetational history of Lighthouse Swamp is different from Barker Swamp. It is evident from Hassell's pollen diagram that chenopods are more significant at all levels in Lighthouse Swamp than at Barker Swamp, probably reflecting greater salinity caused by proximity to the sea.

The evidence from Barker Swamp partly supports the conclusion of Storr *et al.* (1959) and Churchill (1960) that a Tuart woodland or *Eucalyptus-Casuarina* woodland once existed on Rottnest. Evidence was found for the presence of *Eucalyptus marginata*, *E. gomphocephala* and other eucalypts, and occasional *Xanthorrhoea*, but the presence of other tuart woodland species was not confirmed. The tuart/jarrah woodland was not developed over the whole island. Dense stands of *Callitris preissii* occupied the area around Barker Swamp for most of the period from 7500 to 5300 years B.P., and presumably this species was also dominant in other parts of the island.

This study suggests that similar detailed information can be obtained using pollen analysis, in conjunction with detailed sedimentological study, of Holocene intervals from swamps on the Swan Coastal Plain. However, because Barker Swamp is situated on an island and subject to considerable maritime influence it is not a typical coastal plain swamp. To some degree the sedimentary and pollen profile changes must reflect the severence of the land connection and increased maritime influence on the vegetation. Nevertheless, the aridity evident in the early period of Calcilutite deposition is probably the result of increased temperature and/or lower rainfall, factors not strongly influenced by minor changes in the proximity of the sea. Evidence from swamps on the mainland will be useful for further assessment of this mid-Holocene arid period.

Acknowledgements: Peter Thorpe of the Geological Survey of Western Australia provided conventional radiocarbon dates for two samples; the AMS date was provided by the Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand. Ostracod identifications and comments on known habitats were kindly provided by Patrick De Deckker of the Geology Department, The Australian National University. Molluscs were identified by George Kendrick of the West Australian Museum. Phil Ladd of Murdoch University provided considerable assistance to the project with the loan of equipment and with pollen identifications, and the study was suggested and encouraged by Dr. P.E. Playford, formerly Director, Geological Survey of Western Australia. The paper is published with the permission of the Director, Geological Survey of Western Australia.

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